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(54) Abstract Title

Capacitive antenna tuning

(57) The resonant frequency of a Planar Inverted-F Antenna (PIFA) 7 for a mobile telephone is changed by loading the antenna 7 with a capacitance to the ground plane 22. The capacitance is an integrated part of the antenna structure and the antenna 7 is capacitively loaded by using an RF switching component 29 such as a PIN diode or a micro-mechanical switch to switch the capacitance into and out of the antenna circuit, enabling small frequency shifts such as occur between the 1800MHz and 1900MHz GSM bands or between receive and transmit channels. The capacitive load can comprise a third conductor 25 positioned between, and parallel to, an upper radiating plane 21 and the ground plane 22. The space between the upper radiating plane 21, the third conductor 25 and the ground plane 22 can be filled with a dielectric material 34.

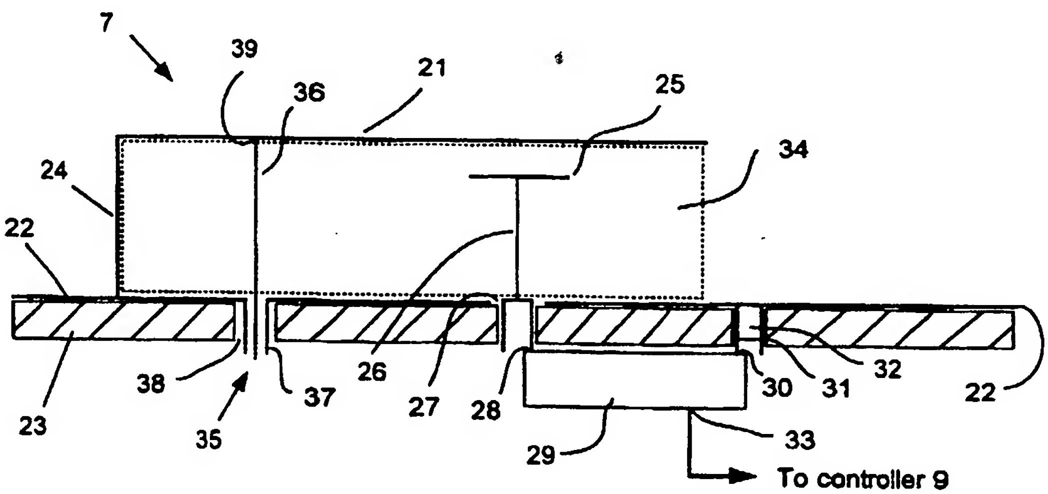

Figure 5

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The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.

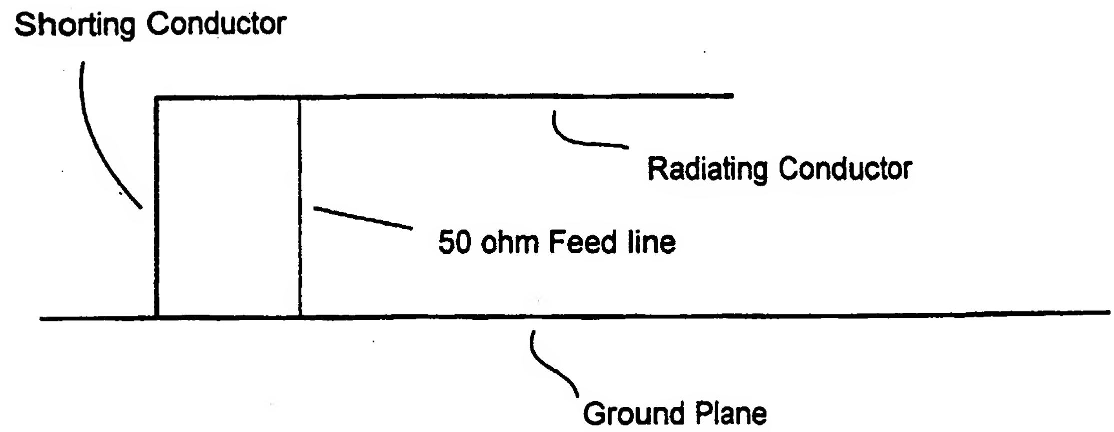

Figure 1

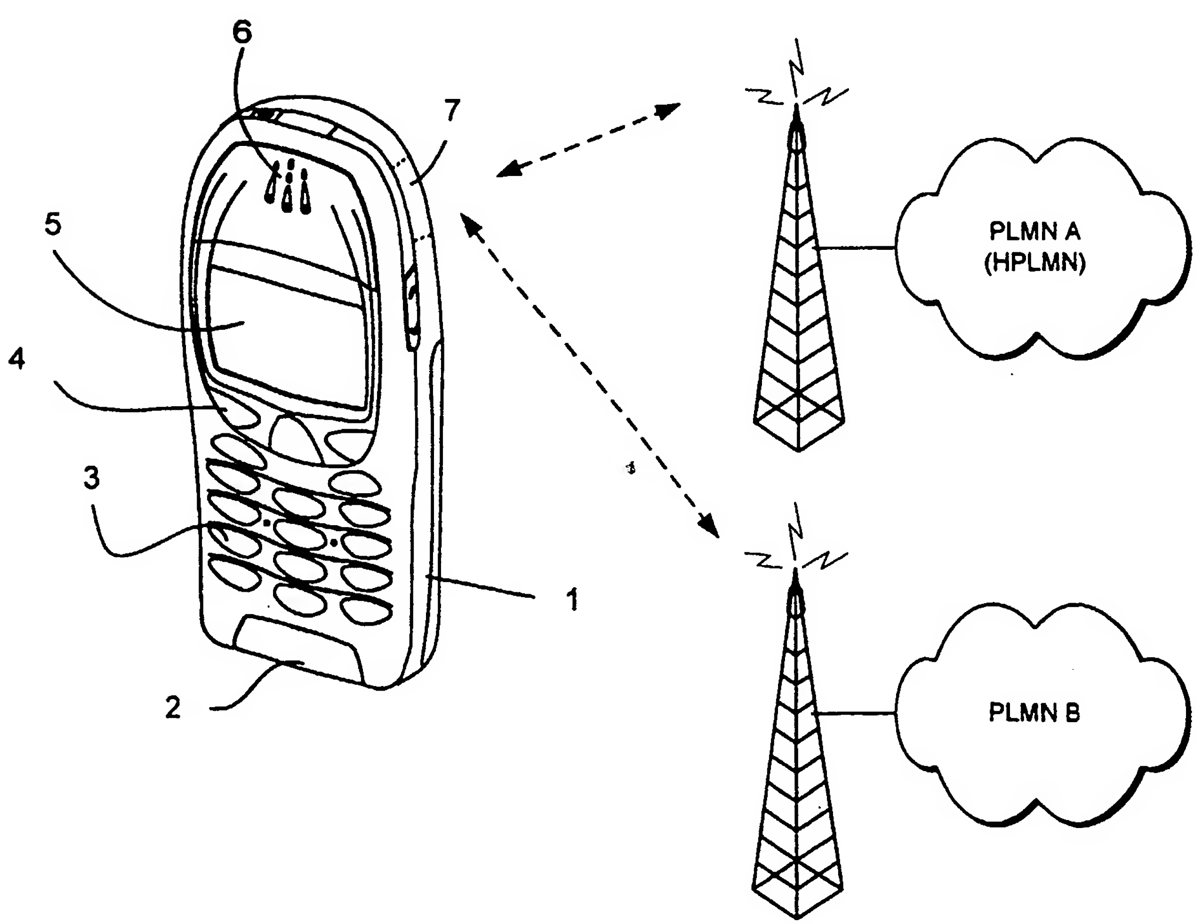

Figure 2

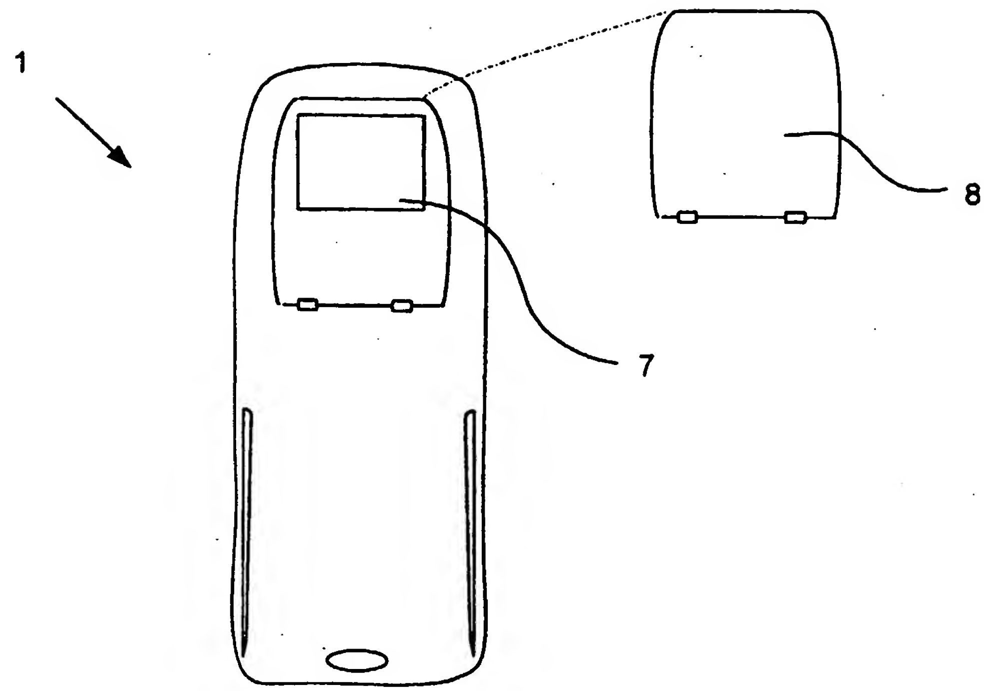

Figure 3

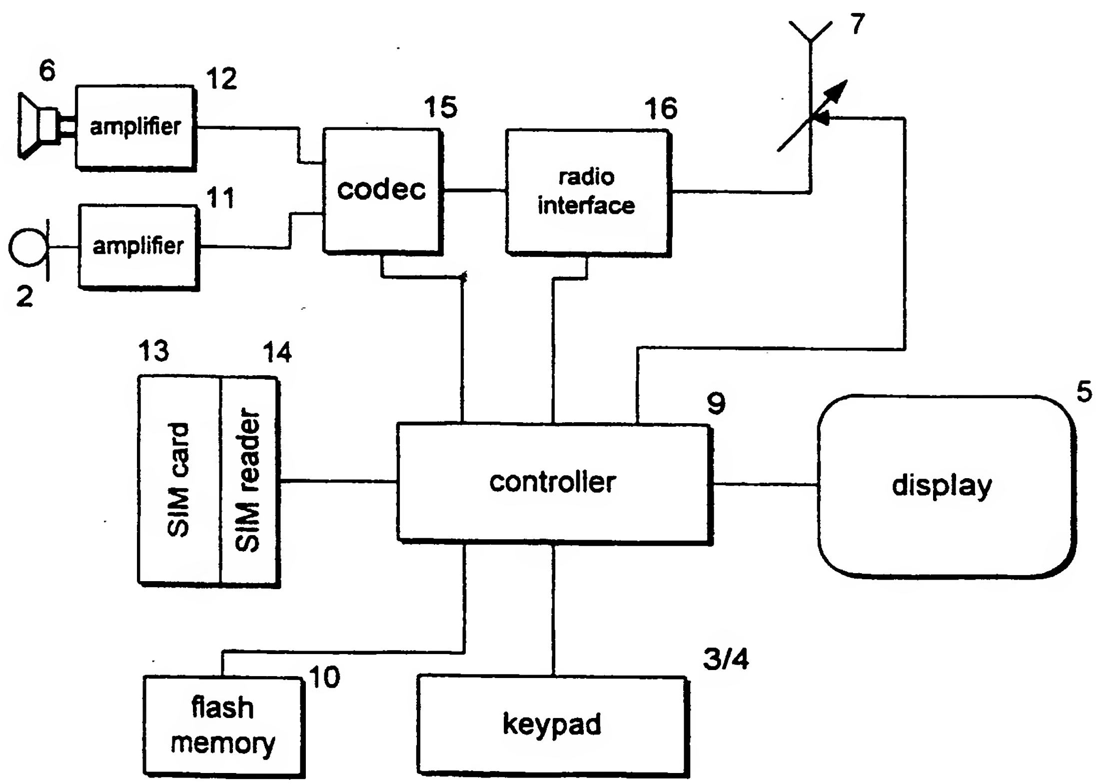

Figure 4

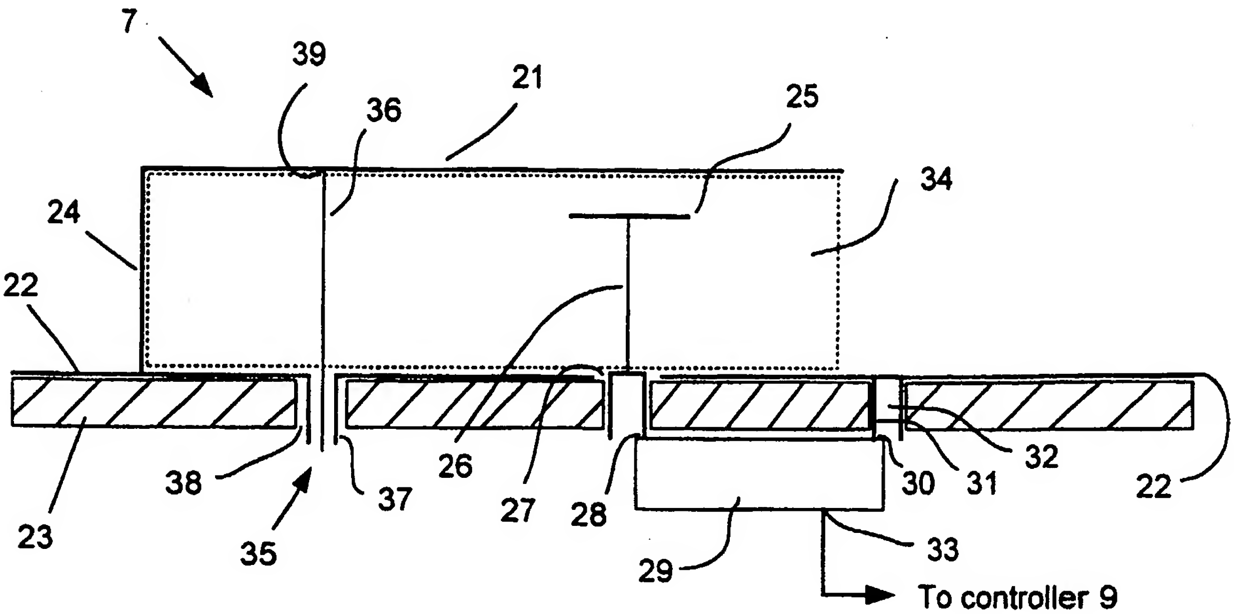

Figure 5

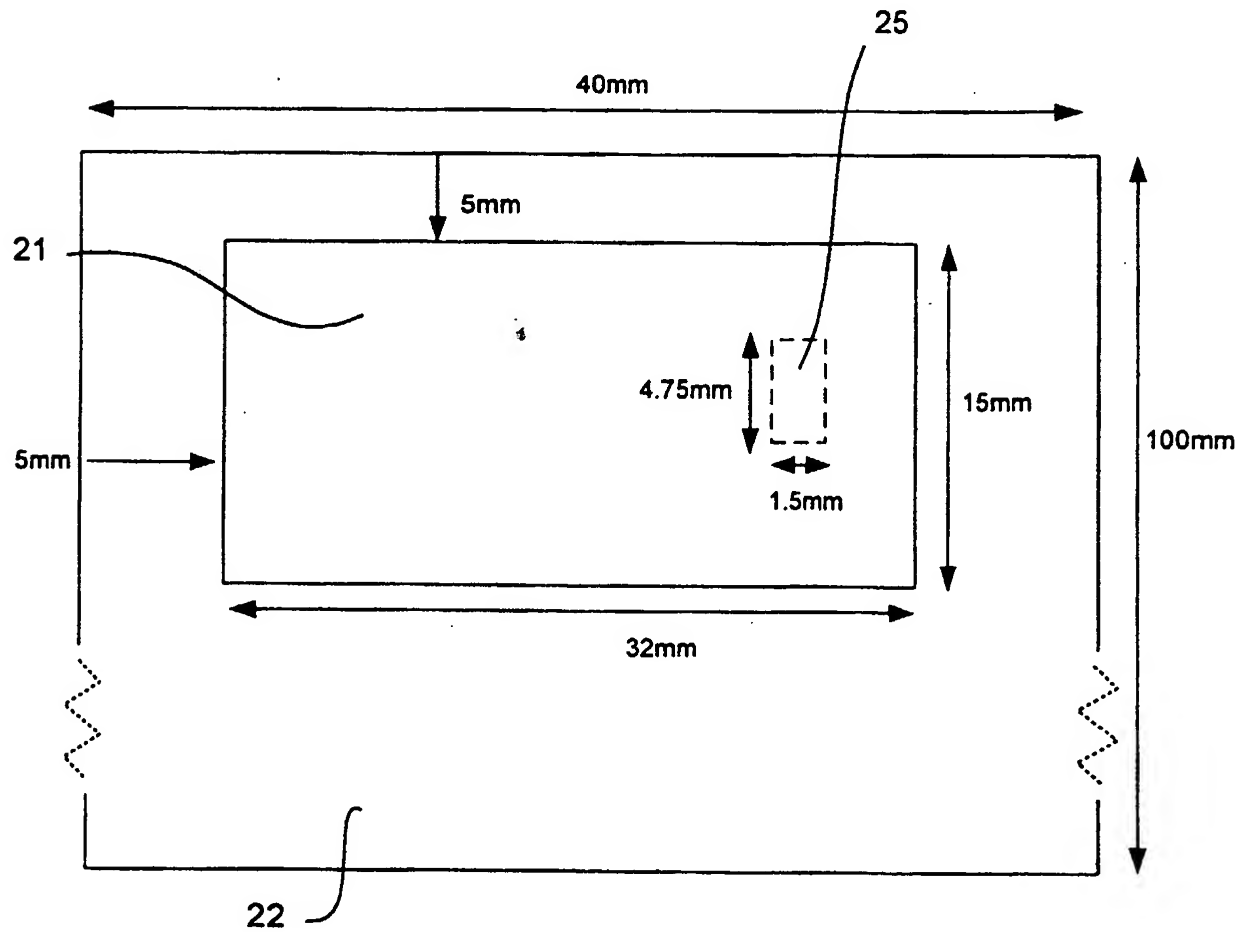

Figure 6

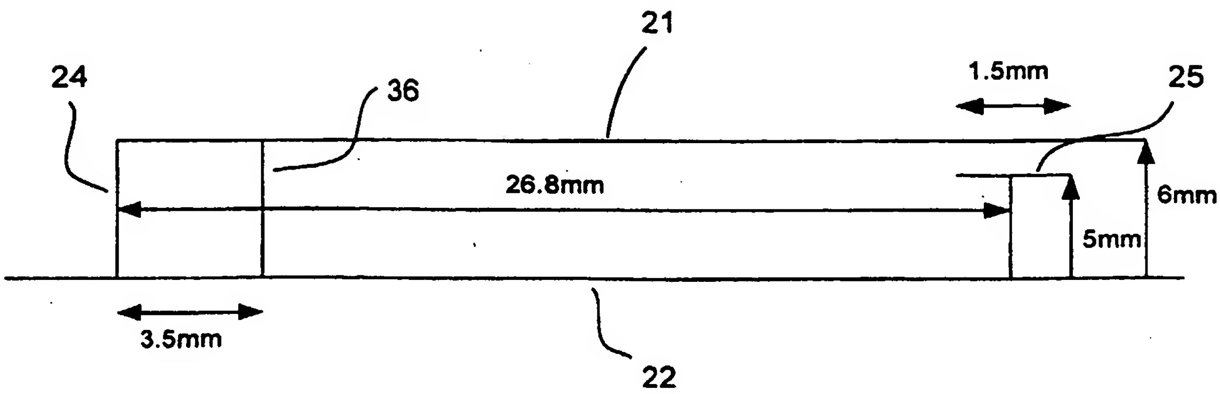

Figure 7

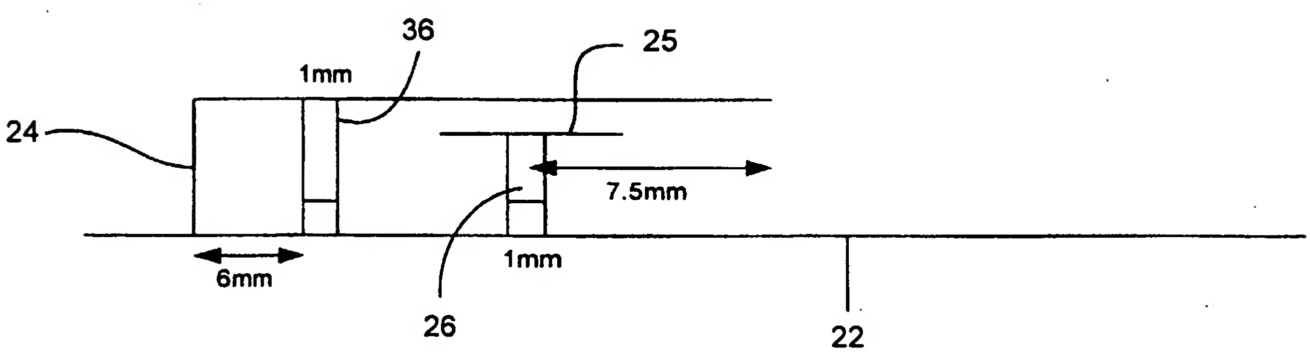

Figure 8

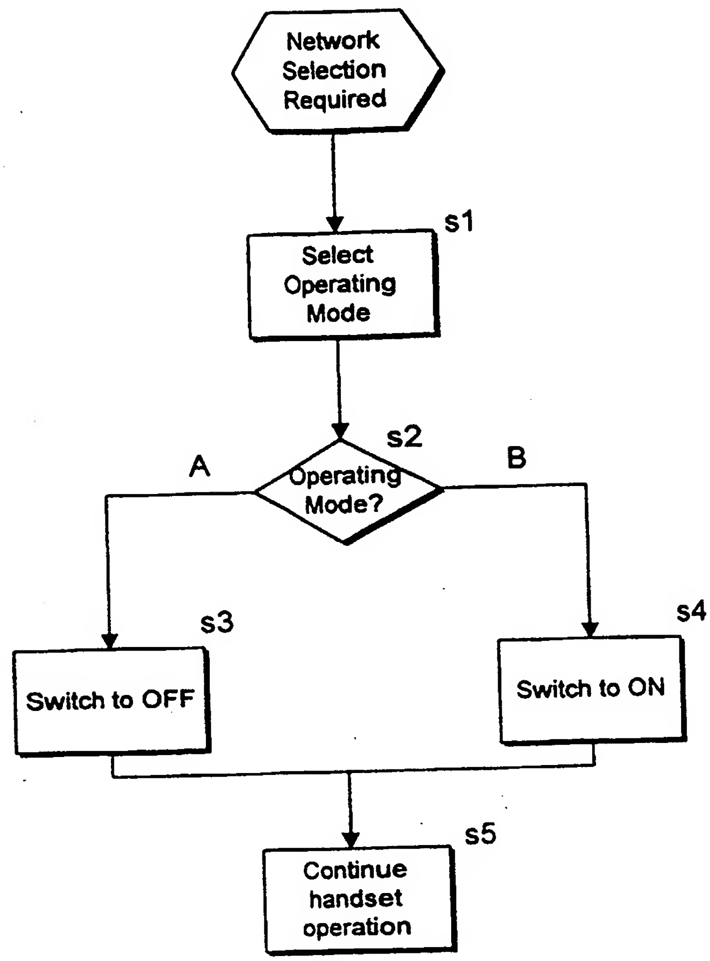
Network Selection Required
s1
Select Operating Mode
s2
Operating Mode?
A
B
s3
Switch to OFF
s4
Switch to ON
s5
Continue handset operation

Figure 9

Capacitive Antenna Tuning

This invention relates to the capacitive tuning of an antenna, particularly but not exclusively to the capacitive tuning of an antenna type known as a planar inverted-F antenna (PIFA).

PIFA antennas are well-known and are well-suited for use as internal antennas in mobile telephones, since they can be made physically small. The name of the antenna derives from its basic structure, in which the antenna element takes the form of an inverted letter F against a ground plane, as shown in Figure 1.

The problem with PIFA antennas is the need to trade-off size and bandwidth, since, in general, the smaller the antenna, the smaller its bandwidth. Since antennas need to be small to fit within modern mobile telephones, a solution is required to the problem of providing sufficient bandwidth for effective operation, including operation across multiple bands. There are two possible approaches to solving this problem, the first being to use multiple antennas and the second being to use a variable tuning scheme, so that the antenna can be made to cover a wider frequency band.

In accordance with the invention, there is provided a tunable antenna comprising an antenna arrangement forming an antenna circuit, means for providing a capacitive load integral to the antenna arrangement, and means for selectively switching the capacitive load into the antenna circuit.

By selectively loading the antenna with a capacitance to the ground plane, its resonant frequency can be changed so that it can be made to cover a wider frequency band. Advantageously, the capacitance is an integrated part of the antenna structure.

The antenna arrangement can be a PIFA antenna which comprises first and second spaced apart conductors, the first conductor comprising a radiating conductor and

the second conductor comprising a ground plane, wherein one end of the radiating conductor is electrically connected to the ground plane.

The antenna can further include a feed conductor connected to the first conductor at a location relatively near to the end at which it is electrically connected to the ground plane.

The capacitive load providing means can comprise a third conductor spaced apart from the first and second conductors and the third conductor can be disposed between the first and second conductors. The third conductor may be connectable to the ground plane via the switching means.

The first, second and third conductors can comprise first, second and third substantially parallel conductive plates, with the third conductive plate extending from an open end of the first conductive plate opposite the end at which it is electrically connected to the ground plane, also referred to as the shorted end, towards said shorted end. The space between the first, second and third plates can be filled with a dielectric material.

The switching means can operate in response to a signal from a controller and can comprise a radio frequency switching component, such as a PIN-diode or a micro-mechanical switch (MEMS).

According to the invention, there is further provided a method of tuning an antenna circuit which comprises an antenna arrangement, including providing a capacitive load integral to the antenna arrangement and selectively switching the capacitive load into the antenna circuit.

The switching of the capacitive load can be in response to a user selection, for example made using the soft keys. The load can be switched in response to a change in frequency band, resulting for instance from a change in the network being accessed by the antenna or by a change in frequency band resulting from switching between transmit and receive frequencies.

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a prior art drawing showing the inverted-F form of a standard PIFA antenna;

Figure 2 is a perspective view of a mobile telephone handset;

Figure 3 is a rear view of the handset of Figure 2;

Figure 4 is a schematic diagram of mobile telephone circuitry for use in the telephone handset of Figure 2;

Figure 5 shows the structure of a tunable PIFA antenna in accordance with the invention;

Figure 6 is a top view of the antenna structure shown in Figure 5;

Figure 7 is a simplified schematic side view of the antenna structure of Figure 5;

Figure 8 is a simplified schematic end view of the antenna structure of Figure 5; and

Figure 9 is a flow diagram illustrating the tuning of the antenna of Figure 5.

Referring to Figure 2, a mobile station in the form of a mobile telephone handset 1 includes a microphone 2, keypad 3, with soft keys 4 which can be programmed to perform different functions, an LCD display 5, a speaker 6 and a tunable antenna 7 which is contained within the housing. The location of the antenna 7 is illustrated in Figure 3, which shows the back of the handset 1 with a rear cover 8 removed.

The mobile station 1 is operable in different configurations to communicate through cellular radio links with individual PLMNs (public land mobile network) shown schematically as PLMN A and PLMN B. PLMNs A and B may utilise different frequency bands. For example, PLMN A may be a GSM 1800 MHz network while PLMN B is a GSM 1900 MHz network.

Generally, the handset communicates over a cellular radio link with its home network PLMN A (shown as HPLMN) in a first configuration i.e. using a frequency band appropriate to PLMN A. However, when the user roams to PLMN B, one of the keys on the handset, for example, one of the soft keys 4, may be operated to

select a second operational configuration i.e. a frequency band associated with PLMN B.

Figure 4 illustrates the major circuit components of the telephone handset 1. Signal processing is carried out under the control of a digital micro-controller 9 which has an associated flash memory 10. Electrical analogue audio signals are produced by microphone 2 and amplified by pre-amplifier 11. Similarly, analogue audio signals are fed to the speaker 6 through an amplifier 12. The micro-controller 9 receives instruction signals from the keypad and soft keys 3, 4 and controls operation of the LCD display 5.

Information concerning the identity of the user is held on a smart card 13 in the form of a GSM SIM card which contains the usual GSM international mobile subscriber identity (IMSI) and an encryption key K_i that is used for encoding the radio transmission in a manner well known per se. The SIM card is removably received in a SIM card reader 14.

The mobile telephone circuitry includes a codec 15 and an rf stage 16 feeding the antenna circuit formed by the tunable antenna 7.

Considering an example where the first configuration is GSM 1800, the codec 15 receives analogue signals from the microphone amplifier 11, digitises them into a GSM signal format and feeds them to the rf stage 16 for transmission through the antenna 7 to PLMN A shown in Figure 1. Similarly, signals received from PLMN A are fed through the antenna 7 to be demodulated in the rf stage 16 and fed to codec 15, so as to produce analogue signals fed to the amplifier 12 and speaker 6.
The antenna 7 is tunable under the control of the controller 9 to the required frequency band for the operational configuration.

As mentioned above, with a conventional dual band/mode phone, when the user roams from the coverage area of PLMN A to PLMN B, the configuration suitable for PLMN B may be manually selected by means of a soft key 4, or can be automatic if the coverage areas for PLMN A and B do not overlap.

Referring to Figures 5, 6, 7 and 8, an antenna 7 according to the invention comprises a first planar conductive copper plate 21 spaced apart from and generally parallel to a second planar conductive copper plate 22. The first conductive plate 21 forms a rectangular patch antenna element 32mm long and 15mm wide which is disposed above and spaced apart from the second conductive plate 22 40mm wide and 100mm long by a distance of 6mm. The second conductive plate comprises a ground plane 22 mounted to a top side of a printed circuit board 23. The printed circuit board 23 is, for example, the board to the underside of which the handset components are mounted. One end of the first conductive plate 21, referred to herein as the shorted end, is connected to the ground plane 22 by means of a conductive shorting element 24.

A third planar conductive plate 25 which forms a capacitive load is arranged between and generally parallel to the first and second plates 21, 22 and spaced apart from both. The third conductive plate 25 is a generally rectangular copper plate 4.75mm long and 1.5mm wide disposed 26.8 mm from the shorted end 24 of the first plate 21. It is spaced 1mm from the first plate 21. The third plate 25 is connected by a conductive element 26 through an opening 27 in the ground plane 22 and the PCB 23 to a first switching connection 28 of a switching component 29 mounted to the underside of the PCB 23. A second switching connection 30 of the switching component 29 is connected by a conductive element 31 to the ground plane 22 via an opening 32 in the PCB 23. A control terminal 33 of the switching component 29 is connected to the controller 9 shown in Figure 4. The switching component comprises a PIN-diode, a micro-mechanical switch (MEMS) or a standard RF-switching component.

The space between the first, second and third plates 21, 22, 25 is filled with a dielectric layer 34, for example a PVC foam with a dielectric constant of 1.1.

The tunable antenna 7 is connected to the rf stage 16 shown in Figure 4 by means of a coaxial feeder line 35 comprising an inner conductor 36 and an outer conductor 37. The inner conductor 36 is connected to the first conductive plate 21 through an

opening 38 in the PCB 23 at a position 39 close to the shorting element 24, for example 3.5mm from the shorting element 24. The outer conductor 37 is connected to the ground plane 22.

Impedance matching of the coaxial line 35 with the antenna 7 is controlled by the connection position 39 of the inner conductor 36 to the first conductive plate 21.

The operation of the invention will now be described in detail.

The switching component 29 operates as a switch to connect and disconnect the third plate 25 from the ground plane 22 under the control of the controller 9, for example in response to the selection of first or second operating modes as described above. Referring to Figure 7, when operating mode selection is required, a user selects an operating mode A or B by using a soft key 4 (step s1). If he selects mode A (step s2), the controller 9 switches the switching component 29 to the OFF position (step s3). In the off position, i.e. when there is no connection between the third conductive plate 25 and the ground plane 22, the antenna 7 behaves as a conventional PIFA antenna and the presence of the plate 25 has little effect on antenna operation.

If the user selects operating mode B (step s2), the controller 9 switches the switching component 29 to the ON position (step s4). When the switch is turned on by a signal from the controller 9, it connects the third conductive plate 25 to the ground plane 22, which has the effect of raising the ground plane 22 towards the first conductive plate 21. As a result, a capacitive load is introduced into the antenna circuit, which changes the resonant frequency of the antenna 7 and so tunes the antenna.

Once the operating mode has been selected and the switch position selected (steps s2 – s4), handset transmit/receive operation continues as normal (step s5).

While the antenna according to the invention has been described as suitable for use between the GSM bands at 1800MHz and 1900MHz, it is also suitable for use in any

situation where small frequency shifts are required, for example those which occur between the receive and transmit channels, for which the controller 9 provides automatic switching of the switching component 29.

It will be understood that while the antenna arrangement has been described with detailed dimensions and relative arrangement of conductive plates, this is merely a specific example of the invention, and use of conductors in forms other than plates, such as conductive wires, and modifications to the dimensions and precise arrangement of the components which do not alter the principles of operation also fall within the scope of this invention.

While specifically described in connection with a PIFA antenna, it will be understood that the principles of the invention extend to other types of antenna, including microstrip antennas and loop and helix antennas.

Claims

1. A tunable antenna comprising:
an antenna arrangement forming an antenna circuit;
means for providing a capacitive load integral to the antenna arrangement; and
means for selectively switching the capacitive load into the antenna circuit.

2. A tunable antenna according to claim 1, wherein the antenna arrangement comprises first and second spaced apart conductors, the first conductor comprising a radiating conductor and the second conductor comprising a ground plane, wherein one end of the radiating conductor is electrically connected to the ground plane.

3. A tunable antenna according to claim 2, further comprising a feed conductor connected to the first conductor at a location relatively near to the end at which it is electrically connected to the ground plane.

4. A tunable antenna according to claim 2 or 3, wherein the capacitive load providing means comprises a third conductor spaced apart from the first and second conductors.

5. A tunable antenna according to claim 4, wherein the third conductor is disposed between the first and second conductors.

6. A tunable antenna according to claim 4 or 5, wherein the third conductor is connectable to the ground plane via the switching means.

7. A tunable antenna according to any one of claims 2 to 6, wherein the first, second and third conductors comprise first, second and third substantially parallel conductive plates.

8. A tunable antenna according to any one of the preceding claims, wherein the space between the first, second and third plates is filled with a dielectric material.

9. A tunable antenna according to any one of the preceding claims, wherein the switching means switches in response to a signal from a controller.

10. A tunable antenna according to any one of the preceding claims, wherein the switching means comprises a radio frequency switching component.

11. A tunable antenna according to claim 11, wherein the switching component comprises a PIN-diode.

12. A tunable antenna according to claim 11, wherein the switching component comprises a micro-mechanical switch (MEMS).

13. A tunable antenna according to any one of claims 1 to 12, wherein the antenna arrangement is of the planar inverted-F antenna type.

14. A mobile telephone including a tunable antenna according to any one of claims 1 to 13.

15. A method of tuning an antenna circuit which comprises an antenna arrangement, including:
providing a capacitive load integral to the antenna arrangement; and
selectively switching the capacitive load into the antenna circuit.

16. A method according to claim 15, comprising switching the capacitive load in response to a control signal from a controller.

17. A method according to claim 15 or 16, comprising switching the capacitive load in response to a user selection.

18. A method according to claim 15 or 16, comprising switching the capacitive load in response to a change in frequency band.

Application No: GB 0102598.0
Claims searched: 1-23

Examiner: Joseph Wellings
Date of search: 3 August 2001

Category	Identity of document and relevant passage	Relevant to claims
X	PAJ abstract of JP 3-181208.	1-5, 9, 11, 12, 15-20

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		